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Si Atomic Layer Epitaxy based on Si_2H_6 and Remote He Plasma Bombardment

by

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Atomic layer Epitaxy(ALE) of silicon has been demonstrated by using remote helium plasma low energy bombardment to desorb H from a H-passivated Si(100) surface at low temperatures and subsequently chemisorbing disilane on the surface in a self-limiting fashion in a Remote Plasma Chemical Vapor Deposition(RPCVD) system in which the substrate is downstream from an r-f noble gas(He or Ar) glow discharge in order to minimize plasma damage. It was found necessary to desorb the H from the Si surface to create adsorption sites for Si bearing species such as Si_2H_6. Optimal He bombardment parameters were determined to be 30 W at 100 mTorr He at 400°C for 1-3 min. Helium was found to be more effective than Ar bombardment because of the closer match of the He and H masses compared to that between Ar and H. Monte Carlo TRIM simulations of He and Ar bombardment of H-terminated Si surfaces were performed to validate this hypothesis and to predict that approximately 3 r H atoms are displaced by the incident He atoms, with no Si atom displacement for the He energies in the range of 15-60 Alternate Si_2H_6 dosing and He low energy bombardment cycles (~100-200) were performed to confirm ALE-mode c was found that the growth per cycle saturates with long Si_2H_6 dosing at a level which increases with He bombardment t.

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Silicon Atomic Layer Epitaxy Based on Disilane and Remote Helium Plasma Bombardment

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Atomic layer Epitaxy(ALE) of silicon has been demonstrated by using remote helium plasma low energy bombardment to desorb H from a H-passivated Si(100) surface at low temperatures and subsequently chemisorbing disilane on the surface in a self-limiting fashion. Silicon substrates were prepared using an RCA clean followed by a dilute HF dip to provide a clean, dihydride-terminated (1x1) surface, and were loaded into a Remote Plasma Chemical Vapor Deposition(RPCVD) system in which the substrate is downstream from an r-f noble gas(He or Ar) glow discharge in order to minimize plasma damage. An *in situ* remote H plasma clean at 250°C for 45 min. was used to remove O and C and provide an alternating monohydride and dihydride termination as evidenced by a 3x1 RHEED pattern. It was found necessary to desorb the H from the Si surface to create adsorption sites for Si bearing species such as Si_2H_6. Remote He plasma bombardment for 1-4 min. was investigated over a range of temperatures (250°C-410°C), pressures (50-400 mTorr) and r-f powers (6-30 W) in order to desorb the H and convert the (3x1) RHEED pattern to a (2x1) pattern which is characteristic of either a monohydride termination or a bare Si surface. It was found that as He pressures and r-f powers were raised the plasma potential and mean free paths were reduced, leading to lower He bombardment energies but higher fluxes. Optimal He bombardment parameters were determined to be 30 W at 100 mTorr He at 400°C for 1-3 min. Helium was found to be more effective than Ar bombardment because of the closer match of the He and H masses compared to that between Ar and H. Monte Carlo TRIM simulations of He and Ar bombardment of H-terminated Si surfaces were performed to validate this hypothesis and to predict that approximately 3 surface H atoms are displaced by the incident He atoms, with no Si atom displacement for the He energies in the range of 15-60 eV. The He bombardment cycles were followed by Si_2H_6 dosing over a range of partial pressures (10^{-7} Torr to 1.67 mTorr), temperatures(250°C-400°C) and times(20 sec to 3 min.) without plasma excitation, because it is believed that Si_2H_6 can chemisorb in a self limiting fashion on a bare Si surface as 2 silyl(SiH_3) species, presumably leading to a H terminated surface once again. The Si_2H_6 dosing pressures and times corresponded to saturation dosing (~10^7 Langmuirs). Alternate Si_2H_6 dosing and He low energy bombardment cycles (~100-200) were performed to confirm ALE-mode of growth. It was found that the growth per cycle saturates with long Si_2H_6 dosing at a level which increases with He bombardment time. At 400°C, for 2 min. He bombardment at 100 mTorr and 30 W, the growth per cycle saturates at ~ 0.15 monolayers/cycle, while for 3 min. He bombardment, the Si growth saturates at ~0.44 monolayers/cycle. This agrees with ALE growth per cycle achieved by Green et al. using UV photo-thermal assisted ALE and is consistent with the steric hindrance presented by adsorbates. It was also confirmed that the growth is achieved only by using alternate He bombardment and Si_2H_6 dosing. Helium bombardment alone for a comparable time (3 min. x100cycles) causes a negligible change of the Si film thickness(<5Å). Similarly, thermal growth using Si_2H_6 under these conditions for (3 min. x100 cycles) causes negligible deposition(<5Å). A novel controller designed to switch gases and the r-f power supply repetitively will also be discussed.